SEE Test Report V3.0
Heavy ion SEE test of MSK5900RH from MS Kennedy

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I. Introduction

This study was undertaken to determine the single event destructive and transient susceptibility of the MSK5900RH adjustable positive voltage regulator. The device was monitored for transient interruptions in the output signal and for destructive events induced by exposing it to a heavy ion beam at the Texas A&M University Cyclotron Single Event Effects Test Facility. Two different tests were performed with two different filters in December 2005 and February 2006. These tests were performed in the frame of LRO project.

II. December 2005 tests

A. Devices Tested

The sample size of the testing is two devices. The devices to be tested have a Lot Date Code of 0442. Package marking is as follows: MSK5900RH, 0442,0433, 61651.

MSK5900 is a hybrid device using bipolar integrated circuits. The device is packaged in a 12 pin metal flat package. The device was prepped for test by delidding.

B. Test Facility

Facility: Texas A&M University Cyclotron Single Event Effects Test Facility, 15 MeV/amu tune)

Flux: 2×10^3 to 2×10^4 particles/cm^2/s.

Fluence: all tests were run to 1×10^6 p/cm^2 or until a sufficient (>100) number of transient events occurred.

The ions and LET values used for these tests are shown in Table 1.

Table 1: Ion LET and range values at target for 0 degree incidence

Ion	LET (MeV•cm^2/mg)	Range (μm)
Ar	8.6	180
Cu	20.3	123
Kr	28.8	122
Xe	53.1	108

C. Test Conditions and Error Modes

Test Temperature: Room Temperature

Bias conditions

Bias conditions are shown in Figure 1. Different test conditions are presented in Table 2. They are representative of different application conditions.

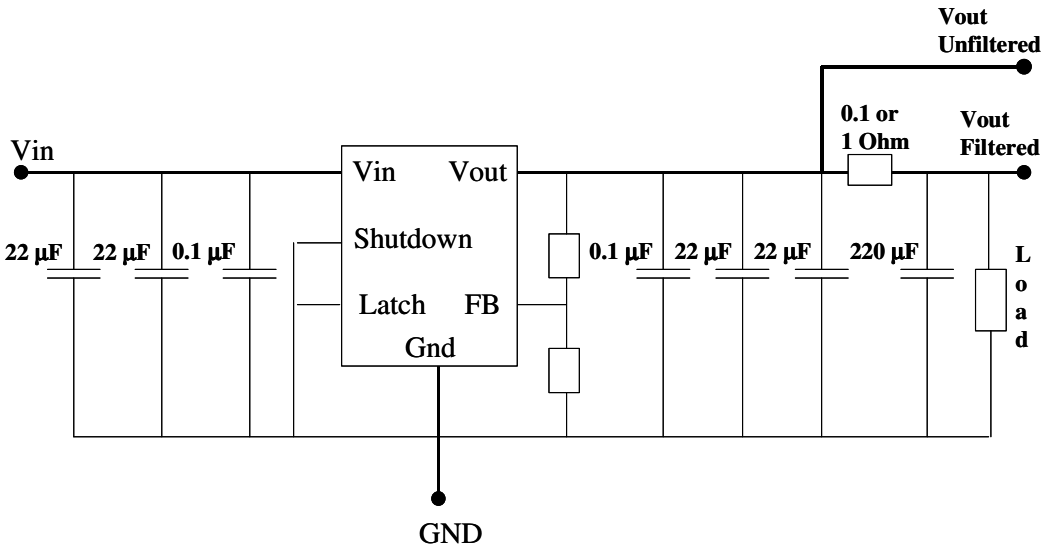

Figure 1: Bias conditions

Table 2: Test conditions investigated

Application	Vin (V)	Vout (V)	Cout (µF)	Iout (mA)
LRO/LOLA	3.0	1.5	44 uF + filter (0.1 ohm, 220 µF)	100
LRO/LOLA	3.3	1.5	44 uF + filter (0.1 ohm, 220 µF)	100
LRO/LOLA	3.3	1.5	44 uF + filter (0.1 ohm, 220 µF)	300
LRO/LOLA	3.3	1.5	44 uF + filter (0.1 ohm, 220 µF)	560
LRO/LOLA	3.3	1.5	44 uF + filter (0.1 ohm, 220 µF)	1000
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	100
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	200
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	300
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	560
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	800
LRO/LOLA	3.6	1.5	44 uF + filter (0.1 ohm, 220 µF)	1000

PARAMETERS OF INTEREST: Input current, output voltage

SEE Conditions: SEL, SEGR, SET

D. Test Methods

Test circuit, as shown in Figure 2, for the adjustable regulator contains a power supply for the input voltage, an electronic load for drawing current, and a digital scope for capturing any output anomalies. Once the, programmable output is present and the load conditions are set, the digital scope is set to trigger on and voltages that are above or below a predetermined threshold (set to 70 mV).

Once the adjustable regulator receives the input voltage, it produces a regulated output, which is determined by an external resistor network (see Figure 1). The digital scope triggered for both voltage dropouts and over voltage conditions at the unfiltered output terminal. The actual voltage regulator output voltage before the filter was 1.535V. The trigger level for dropout was set at 1.46V on scope's channel1. The trigger level for

over voltage was set at 1.6V on scope's channel 2. Scope's channel 3 was connected to the filtered output.

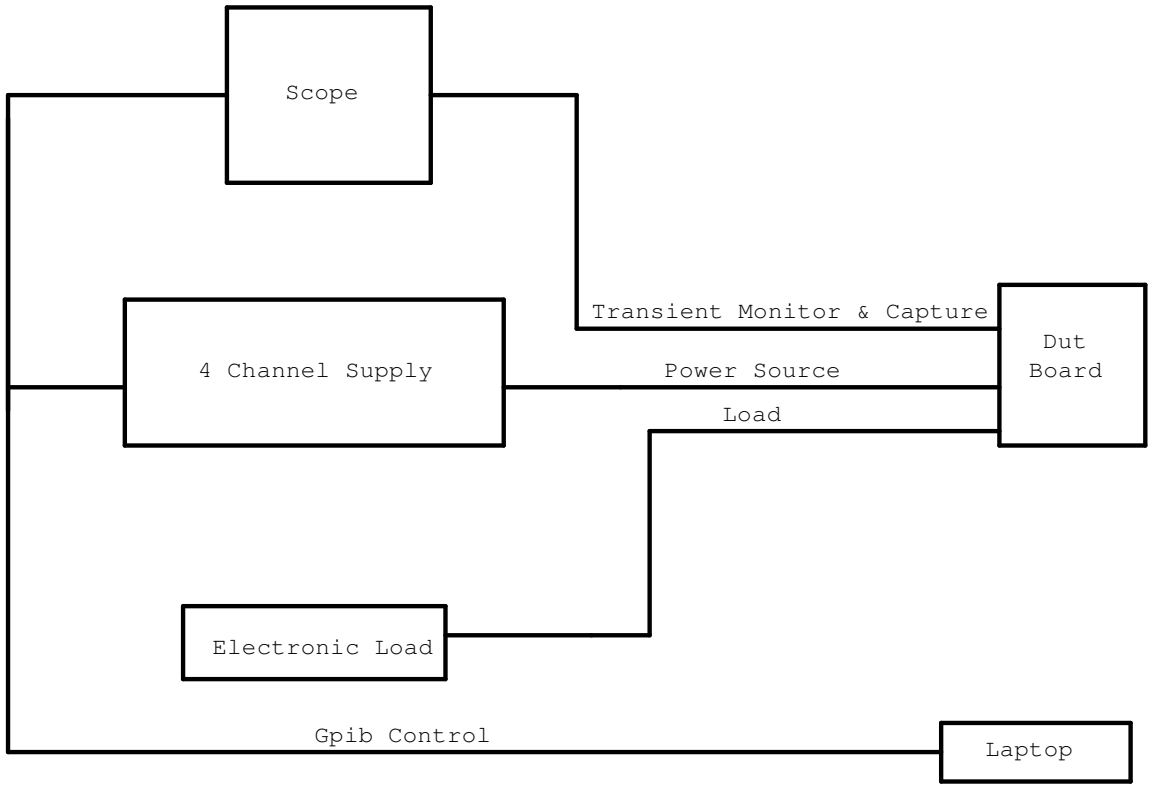

Figure 2. Overall Block Diagram for the testing of the MSK5900RH.

E. Test Results

Detailed are shown in Appendix. No destructive event was observed up to the maximum tested LET of 75 MeVcm^2/mg. MSK5900 is moderately sensitive to SETs. Figure 3 shows the SET cross-sections for the worst-case bias conditions. The part was found most sensitive to SET with the highest input voltage, 3.6V, and the smallest load, 100 mA. For this worst-case bias, LET threshold is about 12 MeVcm^2/mg, and maximum cross section is about 3 x 10^{-4} cm/device.

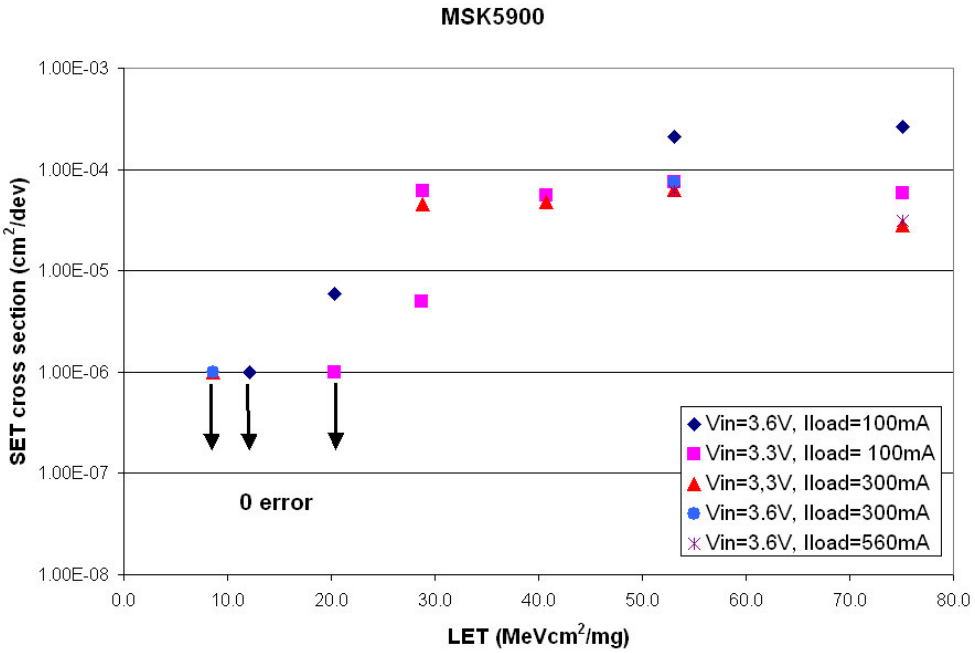

Figure 3: SET cross-section curves

Worst-case transients are shown in Figure 4. SET amplitude is small, less than 200 mV. Worst-case SET duration is about 8 µs. After filter, transient's amplitude is reduced to less than 50 mV.

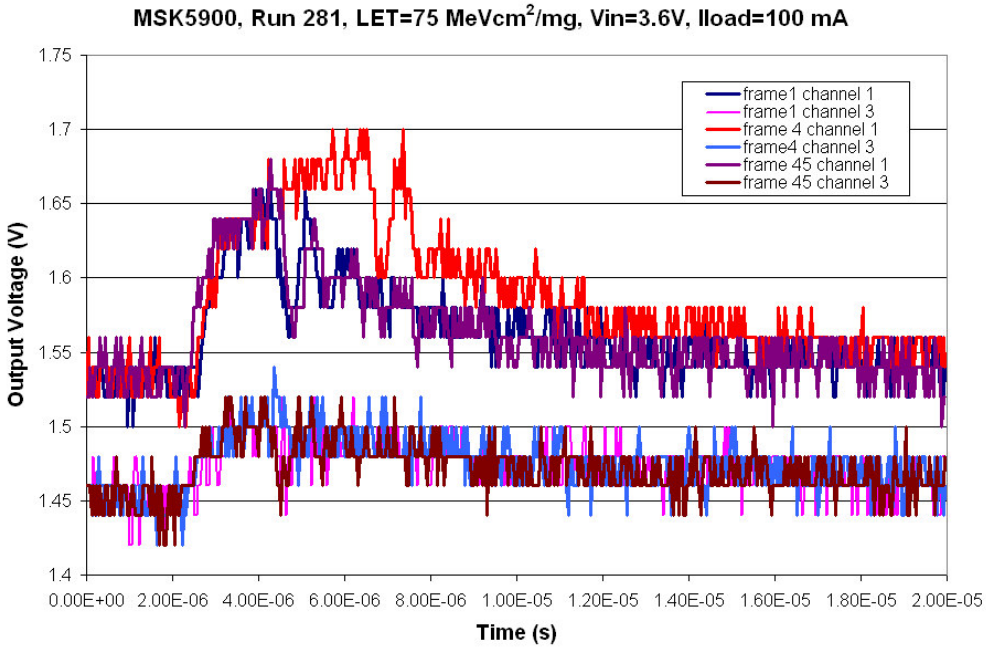

Figure 4: worst-case transients before (channel 1) and after (channel 3) filter

III. February 2006 tests

A. Devices Tested

The sample size of the testing is two devices. The devices to be tested have a Lot Date Code of 0442. Package marking is as follows: MSK5900RH, 0442, 57651, Δ USA.

MSK5900 is a hybrid device using bipolar integrated circuits. The device is packaged in a 12 pin metal flat package. The device was prepped for test by delidding.

B. Test Facility

Facility: Texas A&M University Cyclotron Single Event Effects Test Facility, 15 MeV/amu tune)

Flux: 3×10^3 to 1×10^5 particles/cm^2/s.

Fluence: all tests were run to 1×10^6 p/cm^2 or until a sufficient (>100) number of transient events occurred.

The ions and LET values used for these tests are shown in Table 3.

Table 3: Ion LET and range values at target for 0 degree incidence

Ion	LET (MeV•cm^2/mg)	Range (μm)
Kr	28.8	122
Xe	53.1	108
Xe	55.6	87

C. Test Conditions and Error Modes

Test Temperature: Room Temperature

Bias conditions

Bias conditions are shown in Figure 5. Different test conditions are presented in Table 4. They are representative of different application conditions.

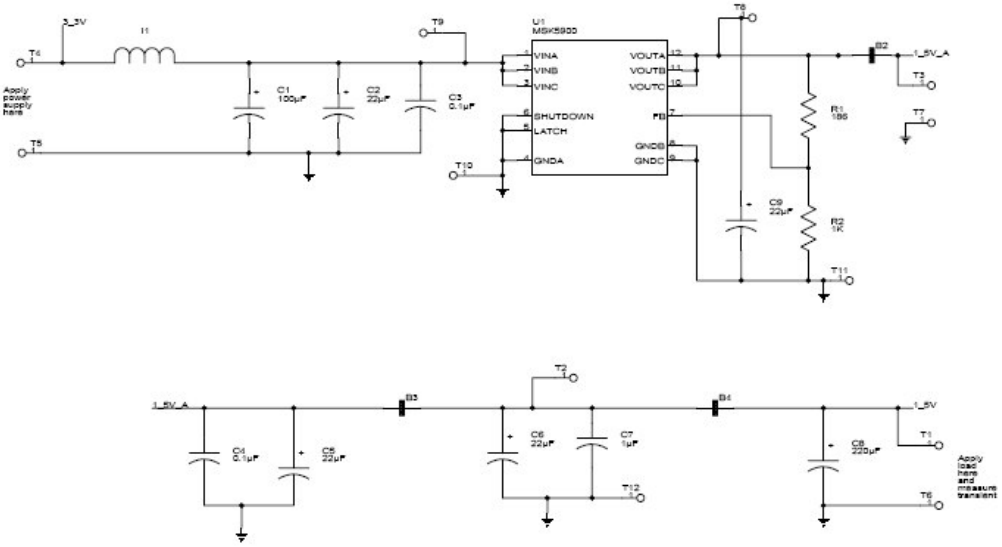

Figure 5: Bias conditions

Table 4: Test conditions investigated

Application	Vin (V)	Vout (V)	Iout (mA)
LRO/C&DH	3.2	1.5	100
LRO/C&DH	3.2	1.5	300
LRO/C&DH	3.2	1.5	500
LRO/C&DH	3.2	1.5	1000
LRO/C&DH	3.3	1.5	10
LRO/C&DH	3.3	1.5	100
LRO/C&DH	3.3	1.5	200
LRO/C&DH	3.3	1.5	300
LRO/C&DH	3.3	1.5	500
LRO/C&DH	3.3	1.5	1000
LRO/C&DH	3.3	1.5	1400
LRO/C&DH	3.4	1.5	300
LRO/C&DH	3.4	1.5	1000

PARAMETERS OF INTEREST: Input current, output voltage

SEE Conditions: SEL, SEGR, SET

D. Test Methods

Test circuit, is shown in Figure 2. The digital scope triggered for both voltage dropouts and over voltage conditions at the unfiltered output terminal (T8). The trigger levels were set at +/-50 mV on scope's channels 1 and 2 for runs 125 to 136. The trigger levels were set at +/-70 mV on scope's channels 1 and 2 for runs 137 to 168. Scope's channel 3 was connected to the filtered output on T1 terminal for runs 125 to 136, and on T2 terminal for runs 137 to 168. Figure 6 shows a picture of the test set-up in the irradiation target room.

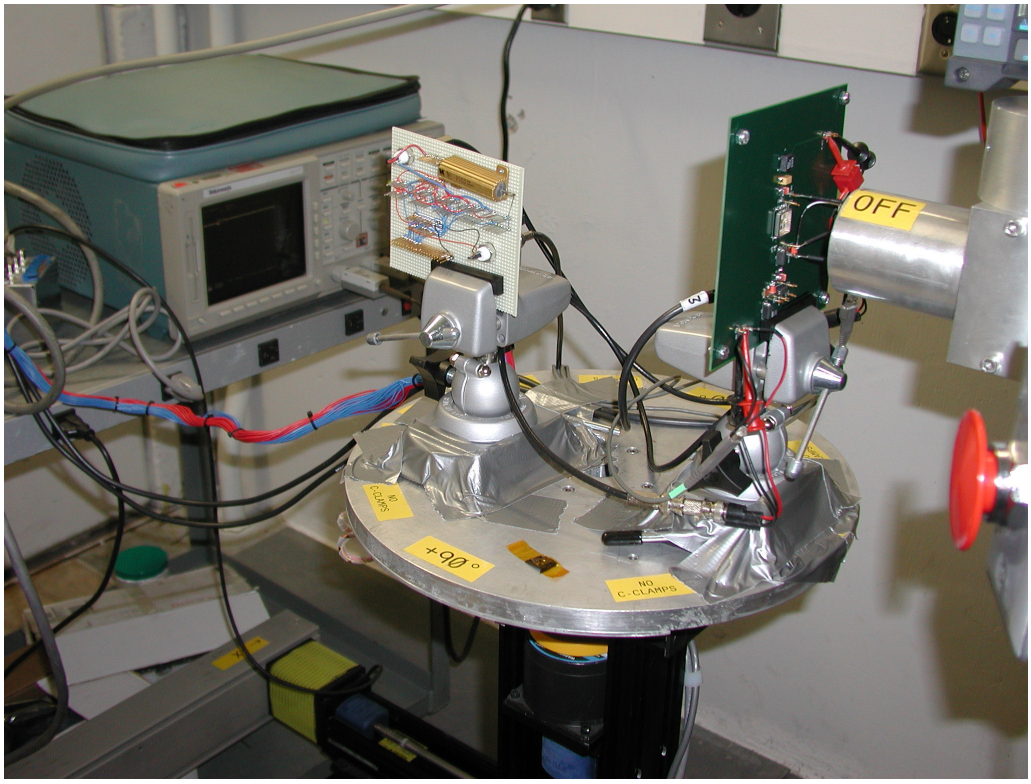

Figure 6: Test set-up and DUT in front of beam output

E. Test Results

Detailed test results are shown in Appendix 2. No destructive event was observed up to the maximum tested LET of 78 MeVcm^2/mg. MSK5900 is moderately sensitive to SET. Figure 7 shows the SET cross-sections with 70 mV trigger level. We did not see a significant effect of input voltage level between 3.2V and 3.4V. The part was found most sensitive to SET with the smallest load, 10 mA. At 1A load, the part is no longer sensitive to SET. The maximum measured cross section is about 4 x 10^{-4} cm/device for the worst-case bias.

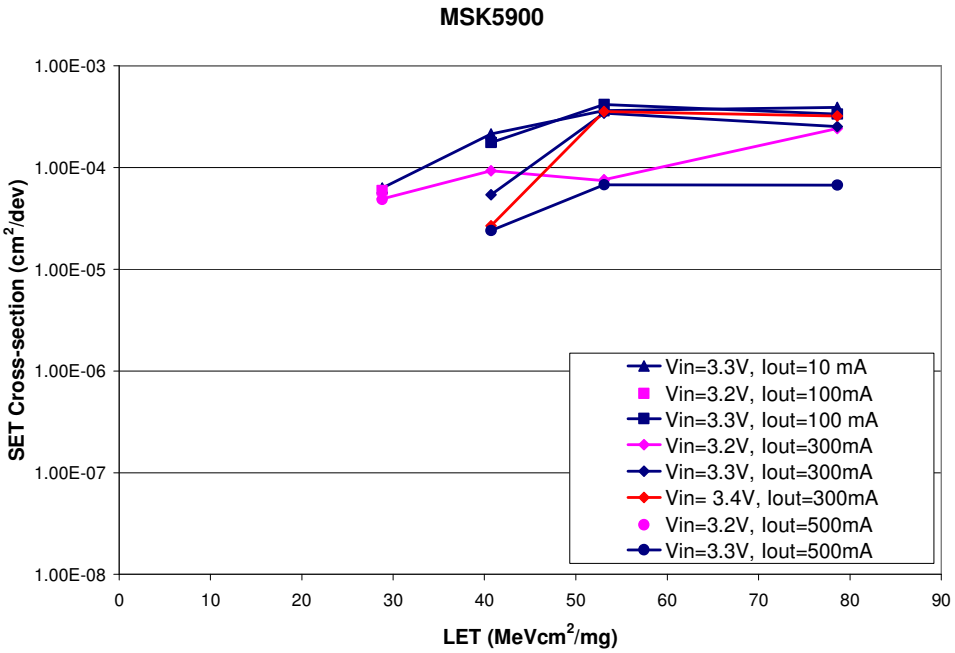

Figure 7: MSK5900 SET cross-section curve

Only one transient waveform was observed. Maximum transient amplitude before filter is about 200 mV. Maximum transient amplitude after the filter on T2 terminal is about 50 mV. Figure 8 shows typical transient before and after filter on T2 terminal.

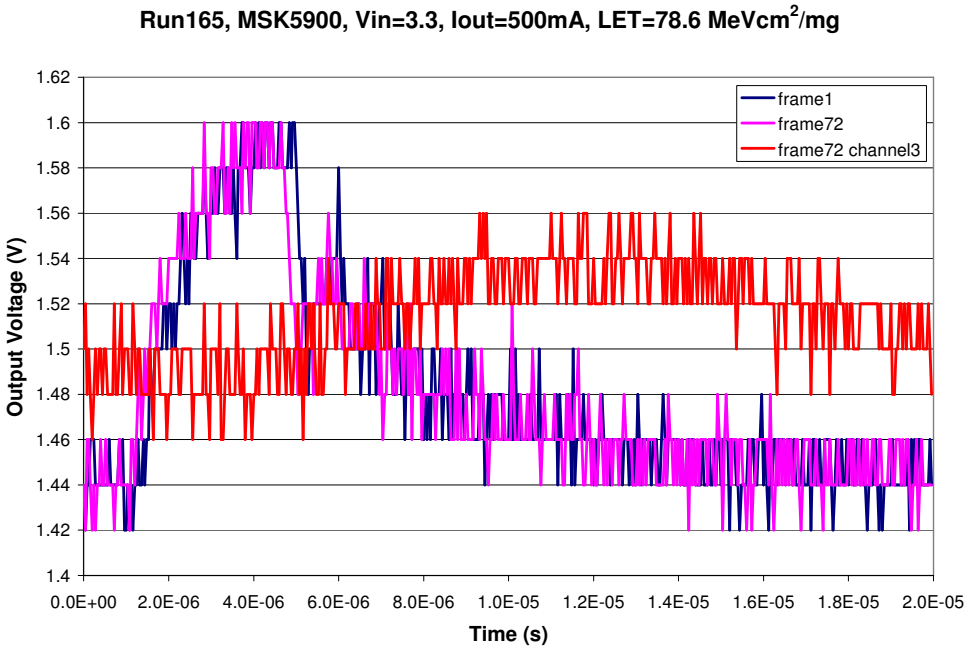

Figure 8: Typical transient waveforms before and after filter.

IV. Recommendations

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1: Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2: Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3: Recommended for usage in some NASA/GSFC spaceflight applications, but requires extensive mitigation techniques or hard failure recovery mode.
Category 4: Not recommended for usage in any NASA/GSFC spaceflight applications.

Based on test results, MSK5900 voltage regulator is a category 2 device. The two filters give similar results. However, the second filter tested in February 2006 does not use a resistor as the first filter tested in December 2005. Therefore, it does not have the disadvantage of voltage drop in the resistor.

Appendix 1: December 2005 test results

Run #	SN #	Vin (V)	Vout (V)	Iout (mA)	Filter	Tilt (°)	eff LET (MeVcm^2/mg)	eff. Fluence (#/cm^2)	SET #	X SET (cm^2/device)
220	433	3.3	1.5	300	0.1 ohm	0	28.8	1.00E+06	45	4.50E-05
221	433	3.3	1.5	100	0.1 ohm	0	28.8	1.00E+06	62	6.20E-05
222	433	3.3	1.5	560	0.1 ohm	0	28.8	1.00E+06	0	0.00E+00
223	433	3.3	1.5	1000	0.1 ohm	0	28.8	1.00E+06	0	0.00E+00
225	433	3.3	1.5	560	0.1 ohm	45	40.7	1.00E+06	0	0.00E+00
226	433	3.3	1.5	300	0.1 ohm	45	40.7	1.00E+06	48	4.80E-05
227	433	3.3	1.5	100	0.1 ohm	45	40.7	1.00E+06	56	5.60E-05
228	433	3.3	1.5	1000	0.1 ohm	45	40.7	1.00E+06	0	0.00E+00
229	44	3.3	1.5	300	0.1 ohm	0	28.8	1.00E+06	0	0.00E+00
230	44	3.3	1.5	100	0.1 ohm	0	28.8	1.00E+06	30	3.00E-05
231	44	3.3	1.5	300	0.1 ohm	0	28.8	1.00E+06	0	0.00E+00
232	44	3.3	1.5	560	0.1 ohm	0	28.8	1.00E+06	0	0.00E+00
233	44	3.3	1.5	560	0.1 ohm	45	40.7	1.00E+06	0	0.00E+00
234	44	3.3	1.5	300	0.1 ohm	45	40.7	1.00E+06	0	0.00E+00
235	44	3.3	1.5	100	0.1 ohm	45	40.7	1.00E+06	26	2.60E-05
264	44	3.3	1.5	100	0.1 ohm	0	53.1	1.00E+06	41	4.10E-05
265	44	3.0	1.5	100	0.1 ohm	0	53.1	1.00E+06	0	0.00E+00
266	44	3.6	1.5	100	0.1 ohm	0	53.1	1.00E+06	78	7.80E-05
267	44	3.3	1.5	300	0.1 ohm	0	53.1	1.00E+06	0	0.00E+00
268	44	3.3	1.5	200	0.1 ohm	0	53.1	1.00E+06	3	3.00E-06
269	44	3.3	1.5	200	0.1 ohm	45	75.1	1.00E+06	3	3.00E-06
270	44	3.3	1.5	100	0.1 ohm	45	75.1	1.00E+06	22	2.20E-05
271	44	3.3	1.5	300	0.1 ohm	45	75.1	1.00E+06	0	0.00E+00
272	433	3.3	1.5	100	0.1 ohm	0	53.1	1.00E+06	76	7.60E-05
273	433	3.3	1.5	300	0.1 ohm	0	53.1	1.00E+06	63	6.30E-05
274	433	3.3	1.5	560	0.1 ohm	0	53.1	1.00E+06	0	0.00E+00
275	433	3.6	1.5	100	0.1 ohm	0	53.1	1.00E+06	212	2.12E-04
276	433	3.0	1.5	100	0.1 ohm	0	53.1	1.00E+06	7	7.00E-06
277	433	3.6	1.5	560	0.1 ohm	0	53.1	1.00E+06	61	6.10E-05
278	433	3.6	1.5	1000	0.1 ohm	0	53.1	1.00E+06	0	0.00E+00
279	433	3.6	1.5	800	0.1 ohm	0	53.1	1.00E+06	0	0.00E+00
280	433	3.3	1.5	100	0.1 ohm	45	75.1	1.00E+06	59	5.90E-05
281	433	3.6	1.5	100	0.1 ohm	45	75.1	1.00E+06	263	2.63E-04
282	433	3.3	1.5	300	0.1 ohm	45	75.1	1.00E+06	28	2.80E-05
283	433	3.3	1.5	560	0.1 ohm	45	75.1	1.00E+06	0	0.00E+00
284	433	3.6	1.5	560	0.1 ohm	45	75.1	1.00E+06	31	3.10E-05
285	433	3.6	1.5	300	0.1 ohm	45	75.1	1.00E+06	75	7.50E-05
286	433	3.3	1.5	300	0.1 ohm	0	8.6	1.00E+06	0	0.00E+00
287	433	3.6	1.5	300	0.1 ohm	0	8.6	1.00E+06	0	0.00E+00
288	433	3.6	1.5	100	0.1 ohm	0	8.6	1.00E+06	0	0.00E+00
289	433	3.6	1.5	100	0.1 ohm	0	8.6	1.00E+06	0	0.00E+00
290	433	3.6	1.5	100	0.1 ohm	45	12.1	1.00E+06	0	0.00E+00
315	433	3.3	1.5	100	0.1 ohm	0	20.3	1.00E+06	0	0.00E+00
316	433	3.6	1.5	100	0.1 ohm	0	20.3	1.00E+06	6	6.00E-06
317	433	3.6	1.5	200	0.1 ohm	0	20.3	1.00E+06	0	0.00E+00
318	433	3.3	1.5	100	0.1 ohm	45	28.7	1.00E+06	5	5.00E-06

Appendix 2: February 2006 test results

Run #	DUT #	Vin (V)	Iout (mA)	Ang (°)	Eff LET (MeVcm^2/mg)	Eff. Fluence (#/cm^2)	SET #	X section (cm^2/dev)	Comments
125	1	3.3	10	0	28.80	2.03E+06	651	3.21E-04	trigger on T8, +/-50mV, filtered output probe on T1
126	1	3.3	10	0	28.80	9.34E+05	315	3.37E-04	
127	1	3.3	100	0	28.80	9.41E+05	321	3.41E-04	
128	1	3.3	200	0	28.80	9.20E+05	332	3.61E-04	
129	1	3.3	300	0	28.80	9.75E+05	336	3.45E-04	
130	1	3.3	500	0	28.80	1.54E+06	106	6.88E-05	
131	1	3.3	1000	0	28.80	3.50E+06	0	0.00E+00	
132	1	3.3	1400	0	28.80	3.52E+06	0	0.00E+00	
133	1	3.4	300	0	28.80	1.78E+06	0	0.00E+00	
134	1	3.4	1000	0	28.80	5.00E+06	0	0.00E+00	
135	1	3.2	300	0	28.80	4.61E+06	253	5.49E-05	
136	1	3.2	1000	0	28.80	7.68E+06	0	0.00E+00	
137	1	3.3	10	0	28.80	4.89E+06	308	6.30E-05	trigger on T8, +/-70mV, filtered output probe on T2
138	1	3.2	100	0	28.80	7.64E+06	456	5.97E-05	
139	1	3.2	300	0	28.80	9.96E+06	492	4.94E-05	
140	1	3.2	500	0	28.80	2.29E+06	111	4.85E-05	
141	1	3.3	10	45	40.73	1.84E+06	394	2.14E-04	
142	1	3.3	100	45	40.73	2.23E+06	393	1.76E-04	
143	1	3.3	300	45	40.73	2.61E+06	141	5.40E-05	
144	1	3.3	500	45	40.73	2.75E+06	132	4.80E-05	
145	1	3.3	1000	45	40.73	9.97E+06	0	0.00E+00	
146	1	3.4	1000	45	40.73	8.13E+06	0	0.00E+00	
147	1	3.2	1000	45	40.73	5.16E+06	0	0.00E+00	
148	1	3.4	300	45	40.73	4.59E+06	123	2.68E-05	
149	1	3.2	300	45	40.73	4.07E+06	380	9.35E-05	
150	1	3.3	10	0	53.10	3.76E+05	137	3.64E-04	
151	1	3.3	100	0	53.10	3.33E+05	139	4.17E-04	
152	1	3.3	300	0	53.10	3.65E+05	125	3.42E-04	
153	1	3.3	500	0	53.10	1.55E+06	105	6.77E-05	
154	1	3.3	1000	0	53.10	1.00E+07	0	0.00E+00	
155	1	3.4	1000	0	53.10	9.98E+06	0	0.00E+00	
156	1	3.2	1000	0	53.10	1.00E+07	0	0.00E+00	
157	1	3.4	300	0	53.10	9.02E+05	320	3.55E-04	
158	1	3.2	300	0	53.10	1.67E+06	124	7.43E-05	
159	1	3.2	300	0	53.10	1.55E+06	118	7.61E-05	
160	1	3.3	10	45	78.63	2.94E+05	115	3.91E-04	
161	1	3.3	100	45	78.63	3.27E+05	110	3.37E-04	
162	1	3.3	300	45	78.63	5.87E+05	149	2.54E-04	
163	1	3.4	300	45	78.63	4.35E+05	140	3.22E-04	
164	1	3.2	300	45	78.63	4.65E+05	113	2.43E-04	
165	1	3.3	500	45	78.63	1.74E+06	117	6.73E-05	
166	1	3.3	1000	45	78.63	9.97E+06	0	0.00E+00	
167	1	3.4	1000	45	78.63	9.97E+06	0	0.00E+00	
168	1	3.3	1000	45	78.63	9.97E+06	0	0.00E+00	